

CLAIMS

What is claimed is:

1. A two-stage hybrid cryocooler comprising:
a first-stage Stirling expander comprising
a first-stage regenerator having a first-stage-regenerator inlet and
a first-stage-regenerator outlet;
5 a second-stage pulse tube expander comprising
a second-stage regenerator having a second-stage regenerator inlet
in gaseous communication with the first-stage-regenerator outlet, and a second-
stage regenerator outlet,
a pulse tube having a pulse-tube inlet in gaseous communication
10 with the second-stage regenerator outlet, and a pulse-tube outlet, wherein the
second-stage regenerator and the pulse tube together provide a first gas-flow path
between the first-stage regenerator and the pulse-tube outlet,
a pulse tube pressure drop structure having a pulse-tube-pressure-
drop inlet in gaseous communication with the pulse-tube outlet, and a pulse-tube-
15 pressure-drop outlet, and
a gas volume in gaseous communication with the pulse-tube
pressure-drop outlet; and
a gas flow shunt providing gaseous communication between the first-stage
regenerator and the pulse-tube outlet, wherein the gas flow shunt provides a
20 second gas-flow path between the first-stage regenerator and the pulse-tube outlet.
2. The hybrid cryocooler of claim 1, wherein the gas flow shunt
provides gaseous communication between a first-stage regenerator location at
which a gas temperature is substantially the same as the gas temperature at the
pulse-tube outlet, and the pulse-tube outlet.
3. The hybrid cryocooler of claim 1, wherein the gas flow shunt
provides gaseous communication between the first-stage regenerator outlet and

the pulse-tube outlet.

4. The hybrid cryocooler of claim 1, wherein the pulse-tube outlet is maintained at the same temperature as the second-stage regenerator inlet.

5. The hybrid cryocooler of claim 1, wherein the pulse-tube outlet is maintained at the same temperature as the second-stage regenerator inlet and wherein the gas flow shunt provides gaseous communication between the first-stage regenerator outlet and the pulse-tube outlet.

6. The hybrid cryocooler of claim 1, wherein the gas flow shunt provides gaseous communication between the first-stage regenerator inlet and the pulse-tube outlet.

7. The hybrid cryocooler of claim 1, wherein the pulse-tube outlet is maintained at an ambient temperature.

8. The hybrid cryocooler of claim 1, wherein the pulse-tube outlet is maintained at an ambient temperature, and wherein the gas flow shunt provides gaseous communication between the first-stage regenerator inlet and the pulse-tube outlet.

9. The hybrid cryocooler of claim 1, wherein the second gas-flow path has a flow capacity of from about 5 to about 30 percent of the first gas-flow path.

10. The hybrid cryocooler of claim 1, wherein the gas flow shunt comprises
a flow-resistance control structure.

11. The hybrid cryocooler of claim 1, wherein the gas flow shunt comprises
a passive flow-resistance control structure.

12. The hybrid cryocooler of claim 1, wherein the gas flow shunt comprises
an active flow-resistance control structure.

13. The hybrid cryocooler of claim 1, wherein the gas flow shunt comprises
a biased-flow-resistance control structure, wherein a pressure drop through
the gas flow shunt is larger when a working gas flows therethrough toward the
5 pulse-tube outlet than when the working gas flows therethrough away from the
pulse-tube outlet.

14. A two-stage hybrid cryocooler comprising:
a first-stage Stirling expander comprising
a first-stage regenerator having a first-stage-regenerator inlet and
a first-stage-regenerator outlet;

5 a second-stage pulse tube expander comprising
a second-stage regenerator having a second-stage regenerator inlet
in gaseous communication with the first-stage-regenerator outlet, and a second-
stage regenerator outlet,

10 a pulse tube having a pulse-tube inlet in gaseous communication
with the second-stage regenerator outlet, and a pulse-tube outlet, wherein the
second-stage regenerator and the pulse tube together provide a first gas-flow path
between the first-stage regenerator and the pulse-tube outlet, and wherein the
pulse-tube outlet is maintained at the same temperature as the second-stage
regenerator inlet,

15 a pulse tube pressure drop structure having a pulse-tube-pressure-
drop inlet in gaseous communication with the pulse-tube outlet, and a pulse-tube-
pressure-drop outlet, and

a gas volume in gaseous communication with the pulse-tube
pressure-drop outlet; and

20 a gas flow shunt providing gaseous communication between the first-stage
regenerator outlet and the pulse-tube outlet, wherein the gas flow shunt provides

a second gas-flow path between the first-stage regenerator and the pulse-tube outlet, and wherein the second gas-flow path has a flow capacity of from about 5 to about 30 percent of the first gas-flow path.

15. A two-stage hybrid cryocooler comprising:
- a first-stage Stirling expander comprising
 - a first-stage regenerator having a first-stage-regenerator inlet and a first-stage-regenerator outlet, and wherein the first-stage regenerator inlet is maintained at an ambient temperature;
 - a second-stage pulse tube expander comprising
 - a second-stage regenerator having a second-stage regenerator inlet in gaseous communication with the first-stage-regenerator outlet, and a second-stage regenerator outlet,
 - a pulse tube having a pulse-tube inlet in gaseous communication with the second-stage regenerator outlet, and a pulse-tube outlet, wherein the second-stage regenerator and the pulse tube together provide a first gas-flow path between the first-stage regenerator and the pulse-tube outlet, and wherein the pulse-tube outlet is maintained at ambient temperature,
 - a pulse tube pressure drop structure having a pulse-tube-pressure-drop inlet in gaseous communication with the pulse-tube outlet, and a pulse-tube-pressure-drop outlet, and
 - a gas volume in gaseous communication with the pulse-tube pressure-drop outlet; and
 - a gas flow shunt providing gaseous communication between the first-stage regenerator inlet and the pulse-tube outlet, wherein the gas flow shunt provides a second gas-flow path between the first-stage regenerator and the pulse-tube outlet.

16. The hybrid cryocooler of claim 15, wherein the second gas-flow path has a flow capacity of from about 5 to about 30 percent of the first gas-flow path.